First year chemistry teaching in health and life sciences degree programmes

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Abstract

In the department of Biomedical Sciences at the University of Ulster the teaching of chemistry to students enrolled on a variety of degree programmes covering a range of subjects in the Life and Health Sciences, has historically presented a problem due to the wide range of entry qualifications held by students. As a minimum the students may be expected to hold a GCSE pass or its equivalent in the Irish Leaving certificate qualification. Exceptionally there may be students enrolled on our degree programmes who have had no experience of specific single subject chemistry teaching. Our aim is to ensure that our first year undergraduates have the necessary competence, in certain relevant areas of chemistry, to progress satisfactorily through higher level modules where chemistry is an essential pre-requisite.

The identification of additional competencies, which are essential to the successful study of chemistry at degree level, led us to the conclusion that a familiarity with certain key areas of mathematics is unavoidable. A number of teaching strategies have been developed which support the traditional lecture and tutorial teaching sessions for those students with little prior experience of mathematics and advanced chemistry.

Apart from student performance in the coursework and examination components of the first semester chemistry module, which is the main indicator of the efficacy of our teaching strategies, we have incorporated an advanced multivariate statistical analysis of the performance of a variety of student groups within the cohort. These groups are identified by the nature of their prior educational experience and entry qualifications.

This sophisticated analysis of performance against prior experience across the cohort is a key element in our monitoring and evaluation of the strategies, which we have developed to achieve a common level of chemistry competence across the cohort.

The teaching strategies and module evaluation techniques employed will be presented in detail together with further developments to be trialled in the academic year 2006-2007. This approach has enabled us to improve the module pass rate from 73% for the academic year 2004-2005 to 91% for the 2005-2006 session.

Key words: chemistry; statistics; multivariate; evaluation; boxplot.

Introduction

In the department of Biomedical Sciences at the University of Ulster the teaching of chemistry to students enrolled on a variety of degree programmes covering a wide

range of subjects in the Life and Health Sciences, has historically presented a problem due to the diverse entry qualifications held by students.

As a minimum, the students may be expected to hold a GCSE pass or its equivalent in the Irish Leaving Certificate qualification. Exceptionally there may be students enrolled on our degree programmes who have had no experience of specific single subject chemistry teaching. Our aim is to ensure that our first year undergraduates have the necessary competence, in certain relevant areas of chemistry, to progress satisfactorily through higher level modules where chemistry is an essential pre-requisite.

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Apart from student performance in the coursework and examination components of the first semester chemistry module, which is the main indicator of the efficacy of our teaching strategies, we have incorporated a multivariate statistical analysis of the performance of a variety of student groups within the cohort. These groups are identified by the nature of their prior educational experience and entry qualifications.

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Interpreting the plots

In this paper, a number of boxplots are used to compare sample distributions. The components of a boxplot are:

1. Outliers – an unusually large or small value denoted by a star (∗)
2. Median – horizontal line within the shaded box
3. The top of the box is the third quartile (Q3)
4. The bottom of the box is the first quartile (Q1)
5. Whiskers – the upper and lower whiskers extend to the highest [= Q3+1.5(Q3-Q1)] and lowest [= (Q1-1.5(Q3-Q1)] values within the upper and lower limits
6. Mean - shown in the box as ⊗

The loadings plot (Rencher, 1995) displays the relationship between variables. Each vector corresponds to one of the analysis variables and its magnitude (length) is proportional to its component loading. Variables which are highly positively correlated approach coincidence in the loadings plot and those which are highly negatively correlated are at 180° to each other.

Strategies

A number of teaching and assessment methods were employed in order to facilitate the progression of students enrolled on an introductory chemistry module at the University of Ulster in the School of Biomedical Sciences.

The Introductory Chemistry module (BMS105C1) is common to students enrolled on the following degree courses:

1. BSc. (Hons) Biology
2. BSc. (Hons) Biomedical Science
3. BSc. (Hons) Dietetics
4. BSc. (Hons) Food and Nutrition
5. BSc. (Hons) Human Nutrition
6. BSc. (Hons) Optometry
7. BSc. (Hons) Pharmacology

Level one students are enrolled on the course with widely differing backgrounds in chemistry and all must, as a minimum, pass the module before they may proceed to level two of their respective courses. Introductory Chemistry is offered in semester one of their first year and Biochemistry is taken in semester two, so an appropriate grounding in chemistry is essential if their study of biochemistry is to be successful.

The teaching methods employed were:

a. Lectures
b. Small group tutorials
c. Laboratory classes
d. Extra tutorials for students with little prior chemistry experience
e. Two intensive tutorials prior to the end of module examination

In addition, a module website (http://www.planetchemistry.com) is maintained and hosts discussion boards, course notes and announcements.

The assessment methods employed were:

a. Computer assisted multiple choice tests every two weeks
b. Assessed laboratory reports
c. One three hour closed book time-constrained end of module examination

Practice multiple choice tests are available on the website in addition to practice tutorial problems and sample examination papers, all of which have been shown to be effective assessment preparation (Adams, Ginn and Ruddick, 1998).

Evaluation

A key process in monitoring the efficacy of all the strategies employed to improve learning and performance is an analysis which requires us to encode students as belonging to various prior experience groups within the modules.

These were identified as:

1. Students having obtained a pass grade in AS or A level chemistry or their equivalents
2. Students with GCSE chemistry or a double award science.

Examination performance

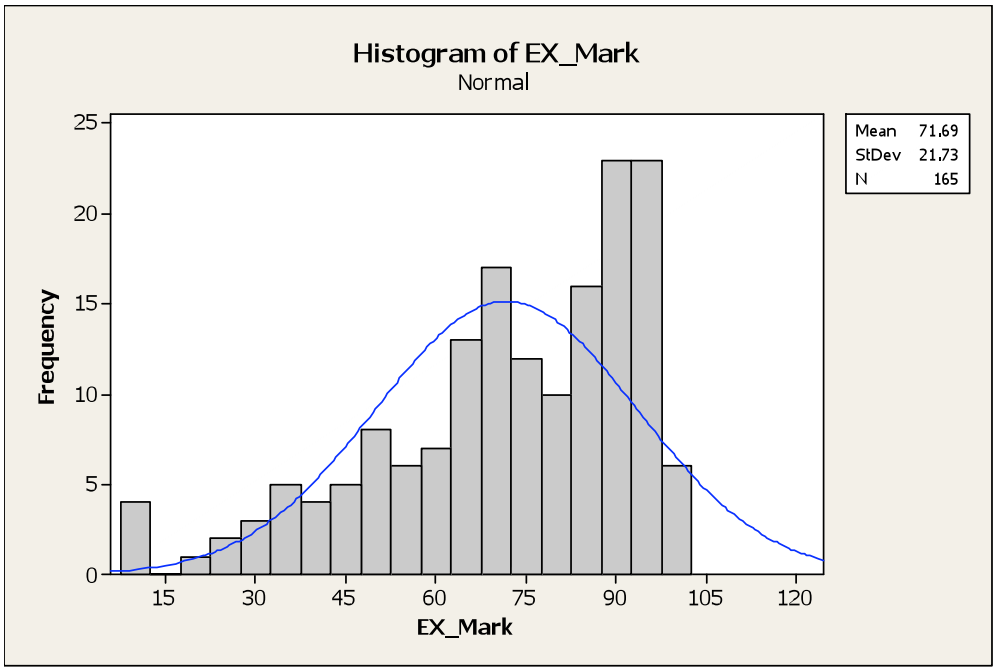

Figure 1: Examination marks of level one students enrolled on Introductory Chemistry (BMS102C1)

Without a detailed statistical analysis of student performance it would be impossible to identify teaching methods which were effective and the student groups which were most likely to benefit from particular teaching strategies.

The examination performance of the 181 students enrolled on the module is shown in Figure 1. Examination marks are skewed towards the high end of the range and there is a poor fit to the normal distribution. However the range is satisfactory. The skewness above 80% is due to those students with good 'A2' grades in chemistry.

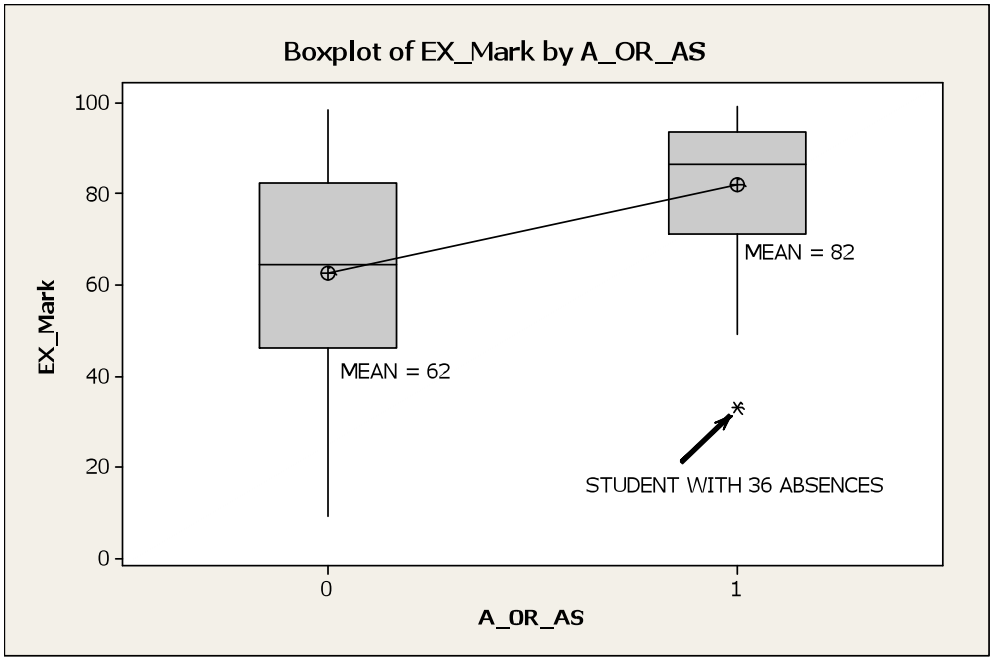

Figure 2: Students with 'A', 'AS', or equivalent level chemistry, on average, score 20% higher in the examination.

Coursework as an indicator of examination performance

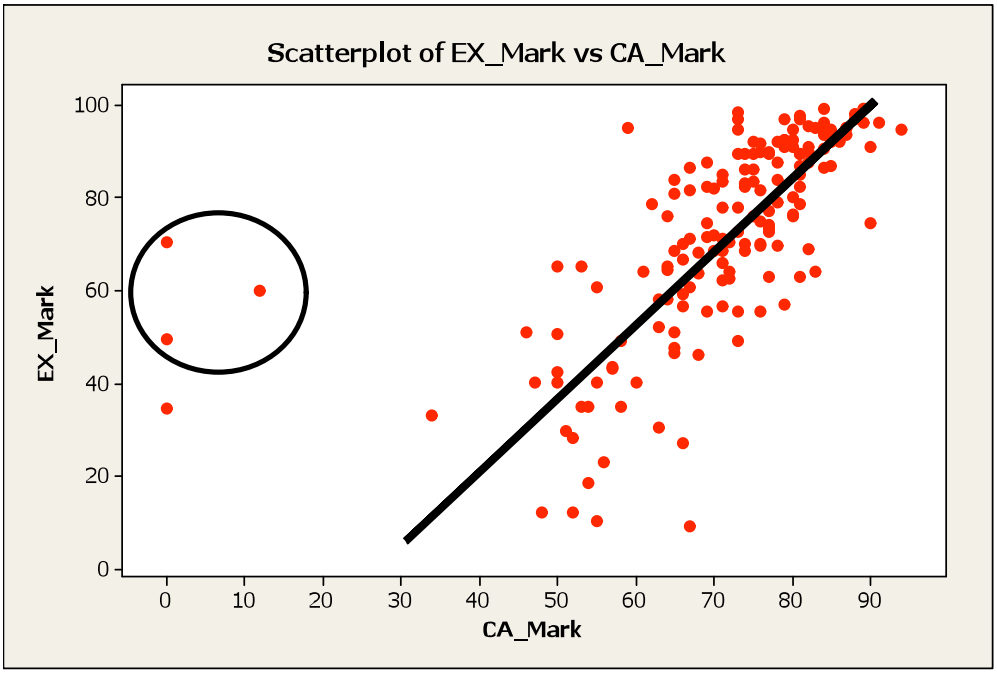

Figure 3: Good correlation between coursework (CA) and examination (EX) mark.

Three students with low coursework and a pass mark in the examination obviously defied all attempts to improve their attendance. A single student failed both the examination and coursework. On average the analysis of the boxplots in Figure 2, shows that in the examination those students with previous AS or A level chemistry score up to 20% higher in the examination.

The coursework components of the module contribute 50% to the overall module mark and it is valuable to decide if ongoing continuous assessment offers an indicator of the mark achieved in the end of module examination. Figure 3 shows a good correlation between the continuous assessment (CA) and the examination (EX) mark. Three students with very low CA marks still managed to obtain a pass mark in the examination. Examination of these students' prior experience showed that they had good A level grades and were competent enough to pass the examination, although

the requirement for a minimum of 35% in the coursework component would attract an overall fail grade in the module as a whole.

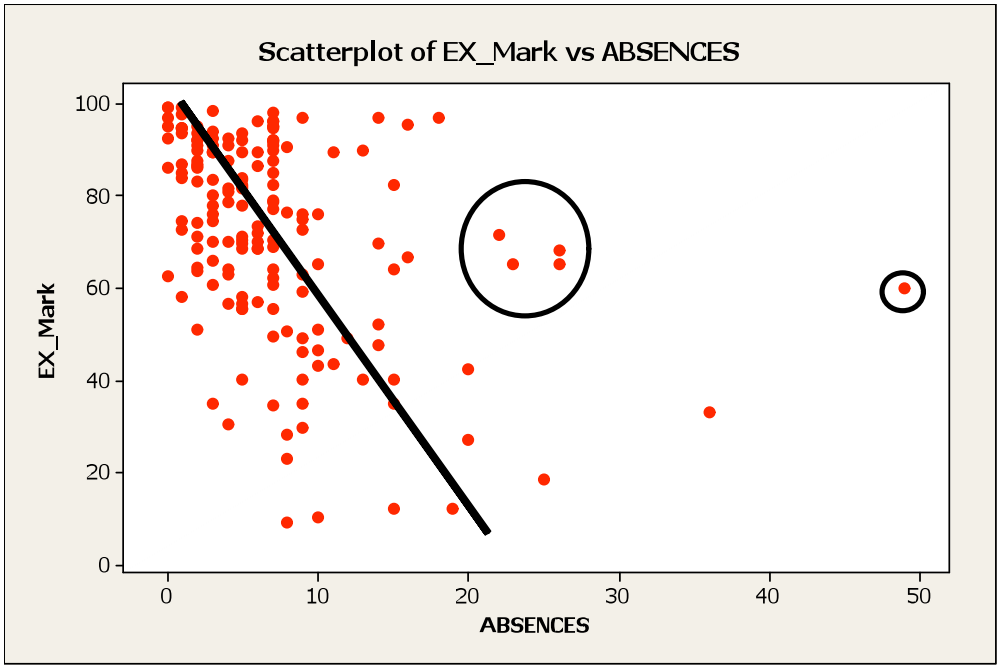

Figure 4: The expected correlation between attendance and examination.

Increased absence from lectures, practicals and tutorials leads to depressed examination marks. Some outliers suggest that 5 poor attenders have sufficient prior 'knowledge' to 'get by' with poor attendance.

At this point it is useful to examine the impact that poor attendance has on the examination score. Figure 4 shows the expected correlation between examination mark and attendance. Five students did, however, gain over 60% in the examination with very poor attendance. This poor attendance defied every effort to produce an improvement despite a very rigid record and advisory system which had been established three years previously to address the perceived problems with attendance and poor examination performance.

Extra tutorials

The additional tutorials offered to support those students with little or no background in chemistry had a good uptake, both with the target audience and also with some conscientious students who had previously studied 'A' or 'AS' level chemistry, but who believed that they might benefit from extra problem-solving sessions and help. From the box plots in Figure 5 it is clear that, for students with no AS or A level chemistry, their examination mark steadily improves if they attend one or two tutorials while those attending five or six extra tutorials obtain marks comparable to those obtained by students with previous AS or A level chemistry.

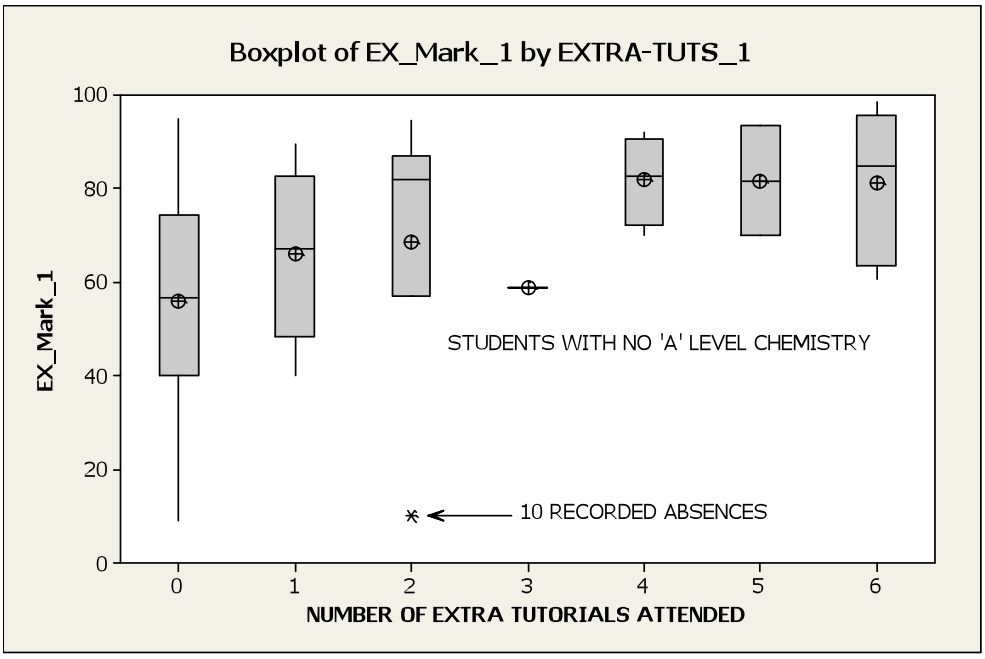

Figure 5: Students with no A level chemistry experience (A or AS level) or with no chemistry at Irish Higher or Irish Ordinary level improve their probability of passing by attending at least one extra 'voluntary tutorial'.

It may be that the students who failed to achieve at least a pass grade were not sufficiently motivated to attend extra tutorial classes and this lack of motivation would be reflected in their level and quality of examination preparation. For the students with AS or A level chemistry Figure 6 shows that attending only one extra tutorial was sufficient to obtain a mark of around 70% or better in the examination.

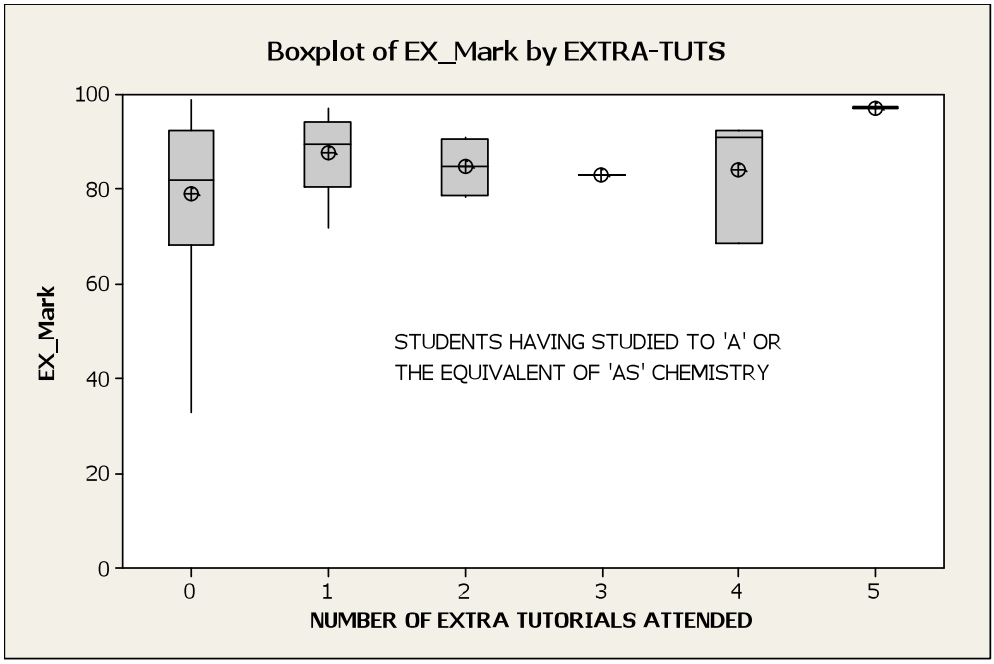

Figure 6: In all, 6 extra 'voluntary' tutorials were offered in semester one. No students who attended at least one extra tutorial failed the examination.

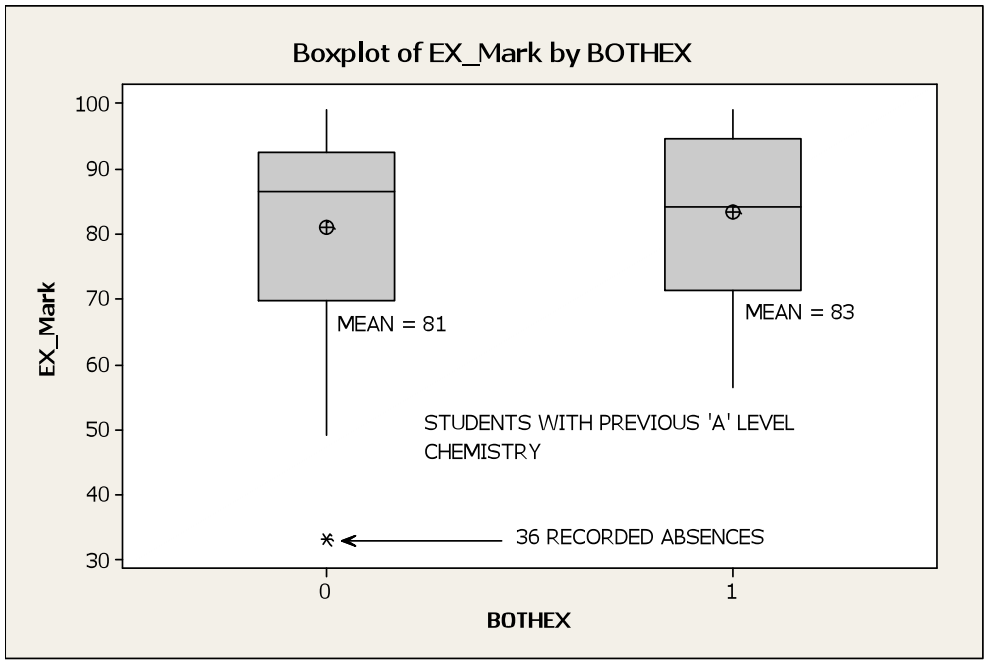

Figure 7: Students with previous A and AS level experience generally do not exhibit improved examination performance by attending both pre-examination revision tutorials. It is, however, not detrimental to their performance and may be viewed as a 'confidence-building' exercise.

Pre-examination tutorials

The final measure put in place was a series of two pre-examination revision tutorials held after the Christmas vacation and in the week prior to the module examination. These were trialled as it was apparent that formal classes finished one week before Christmas and examinations did not begin until the second or third week of January. For some students this four week lack of support proves to be a barrier to good examination performance. The box plots in Figure 7 show that the pre-examination revision tutorials made no significant difference to examination performance for students with a previous AS and A level chemistry background, nevertheless the tutorials are viewed as a worthwhile 'confidence building' exercise. On the other hand for students with no previous AS or A level experience, Figure 8, attendance at the pre-examination tutorials offered an opportunity to improve their examination mark by at least 20% when compared with the student group who elected not to attend the non-compulsory revision tutorials.

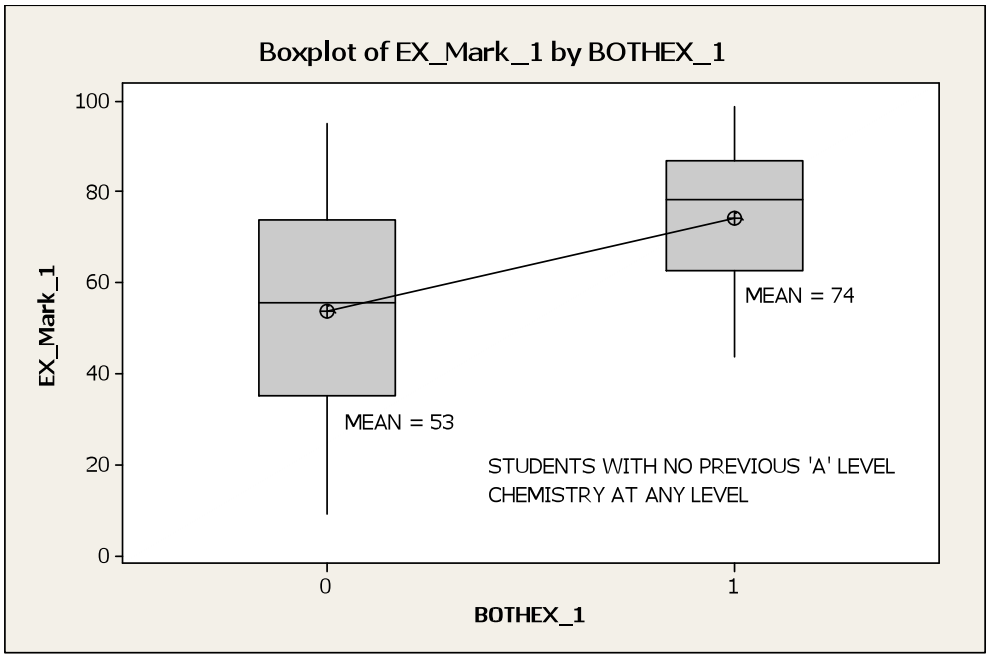

Figure 8: Attendance at both pre-examination revision tutorials improved the mean examination mark of students with no chemistry A levels by 21% on average. None of these students gained lower than a pass grade.

Prior experience

The thorny question of which subjects to study at AS and A level is a perennial and difficult one for many students, particularly when the decision making process is driven by a desire to avoid the 'difficult' subjects which they perceive to be mathematics, chemistry and physics. The requirement of a number of degree courses, in the School of Biomedical Sciences at the University of Ulster, for a semester one chemistry module to underpin future study in levels two and three is clearly at odds with the AS and A level subjects studied by a proportion of our enrolment.

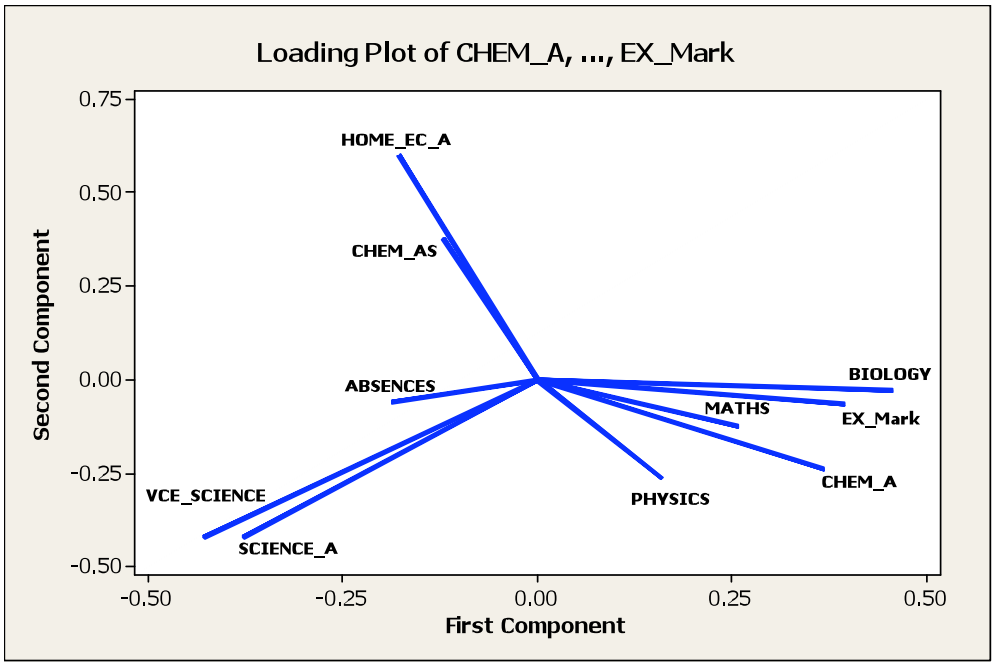

Figure 9: Loadings plot of the AS and A levels taken with the Introductory Chemistry examination mark as variables.

It is instructive to examine the relationship between the BMS102C1 examination mark and AS and A level backgrounds of our level one students. The multivariate loadings plot in Figure 9 shows that a pass grade in A level biology, chemistry, physics and mathematics is correlated with a higher BMS105C1 examination mark, physics to a lesser extent than the other two A levels. An A level in home economics, unsurprisingly, does not correlate with a high BMS105C1 examination mark. The

numbers of absences during the semester are negatively correlated with the examination mark as are the study of A level science and vocational qualifications in science. Somewhat surprisingly, a pass at 'AS' level chemistry is negatively correlated with a high examination mark in BMS105C1. These students did not progress to A level chemistry and it seems likely that their experience of the subject was not a happy one and that their discomfort with the subject was maintained throughout the module under discussion. Their story is not a failure as all these students passed the examination and the module, but their AS level chemistry studies contributed very little to their success in BMS105C1.

Conclusions

Implementing a number of simple support strategies for students has enhanced the module pass rate from 73% (2004-2005) to 93% (2005-2006). The strategies themselves are not particularly innovative. This paper demonstrates that their application is effective in teaching a large group of students university level chemistry when the prior experience of the group may not include AS or A level chemistry. The most important lesson to be drawn from this experience is that the detailed structure and information available in the data and personal profiles of the students may be extracted with the appropriate descriptive and multivariate statistics. While the use of such statistical methods is not an everyday activity for staff involved in teaching and evaluating modules in the HE sector, their use offers the facility to extract the maximum amount of information from large and varied data sets. On many occasions the ability to demonstrate the necessity for additional classes on already heavily loaded timetables may be the only argument which persuades cost centre managers or heads of department to allocate resources in terms of staff time to activities which may seem irrelevant and pedantic. Student retention is a key issue in many areas of tertiary level education and staff teaching students, who have been ill-prepared for their chosen

degree by an inappropriate choice of A levels, will be keenly aware that the only cure is extra staffing to facilitate additional classes to raise all students to common academic skills levels.

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